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04OCT02 E753117-1 D02651
P01/7700 0.00-0222962.3

Request for grant of a patent

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1. Your reference	575GB
2. Patent application number *(The Patent Office will fill in this part)*	0222962.3
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Renishaw plc New Mills Wotton-under-Edge Gloucestershire, GL12 8JR
Patents ADP number *(if you know it)*	2691002
If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4. Title of the invention	Laser System
5. Name of your agent *(if you have one)*	M J Fowler et al
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Renishaw plc, Patent Department New Mills Wotton-under-Edge Gloucestershire, GL12 8JR United Kingdom
Patents ADP number *(if you know it)*	8276297002

	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	-	-	-

	Number of earlier application	Date of filing *(day / month / year)*
7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	-	-

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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Continuation sheets of this form	0
Description	8
Claim *(s)*	0
Abstract	0
Drawing *(s)*	2 only

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10. If you are also filing any of the following, state how many against each item.

Priority documents	0
Translations of priority documents	0
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0
Request for preliminary examination and search *(Patents Form 9/77)*	0
Request for substantive examination *(Patents Form 10/77)*	0
Any other documents *(please specify)*	0

11. I/We request the grant of a patent on the basis of this application.

Signature [signature] Date 04.10.2002

AGENT FOR THE APPLICANT

12. Name and daytime telephone number of person to contact in the United Kingdom A Iles 01453 524464

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LASER SYSTEM

This invention relates to a laser system and in particular the alignment of a laser beam in a laser system.

It is known to control the orientation of a laser beam using two or more rotating prisms. Depending on the number of rotating prisms and their relative orientations one-dimensional or two-dimensional alignment of a laser beam can be achieved. Rotation of one prism deviates the beam direction in one plane. A second rotating prism can, if rotated in the same direction increase the degree of deviation within this plane or, if orientated differently with respect to the laser beam it can deviate the beam direction in a different plane. Problems that occur with known methods of controlling the orientation of a laser beam include the fact that the prisms can be expensive as in order to achieve the objective they often have to be matched pairs of prisms. Adjustment of the prisms can be time consuming and in some circumstances unintuitive. The amount of adjustment of the beam direction in a given plane may also be limited.

According to a first aspect of the present invention there is provided a laser system having an optical axis comprising:

a laser source which generates a laser beam;

first and second adjustment means which are adjustable relative to the optical axis;

characterised in that the laser beam is directed from a point which is non-parallel to the optical axis and the first and second adjustment means deviate the

laser beam onto the optical axis.

Preferably the first and second adjustment means are relatively positioned such that the first and second adjustment means, when adjusted, deviate the laser beam in first and second planes respectively each of which is perpendicular to the optical axis.

Preferably the laser system further comprises at least one mirror positioned in the laser beam path, whereby the at least one mirror is at an angle offset to the optical axis wherein the first and second adjustment means deviate the laser beam onto the optical axis and the at least one mirror reflects the laser beam along a second optical axis.

According to a second aspect of the present invention there is provided a laser interferometer system having an optical axis comprising:

a laser source for providing a first laser beam;

means to provide a second laser beam from the first laser beam;

interference means for providing an interference beam from a supposition of the first and second laser beams;

a detector for detecting the interference beam; and

first and second adjustment means which are adjustable relative to the optical axis;

characterised in that the a first laser beam is directed from a point which is non-parallel to the optical axis and the first and second adjustment means deviate the first laser beam onto the optical axis.

Preferably the laser interferometer system further comprises a mirror in the path of the first laser beam whereby the mirror is at an angle offset to the optical axis wherein the first and second adjustment means deviate the beam onto the optical axis and the at least one mirror reflects the laser beam along a second optical axis.

The first and second adjustment means are preferably first and second prisms which rotate relative to the optical axis.

Alternatively the first and second adjustment means are a prism and a rotatable adjustable clamp which houses the prism. Such a clamp may be square and comprise four corner screws which may be tightened or loosened independently thus enabling deviation of a laser beam which passes through the prism. This is described in more detail in published application WO00/57228.

The invention will now be described by example and with reference to the accompanying drawings of which:

Fig 1 shows a plan view of a laser system according to the invention;

Fig 2 shows schematically an alternative laser system according to the invention;

Fig 3 shows a laser interferometer system according to the invention.

Fig 1 shows a laser system having a laser source 10 which provides a laser beam 12 at an angle which is non-parallel to the optical axis 14. The laser beam 12 is offset to the optical axis 14 in two directions in the z direction by an angle a and in the y direction by

an angle b. Lying on the optical axis is a first prism 16 and a second prism 18 both of which are rotatable 20 about the optical axis 14.

The laser beam 12 from the laser source 10 is incident on the first prism 16 which is rotatable 20 about the optical axis 14. Rotation of beam 16 causes deviation of laser beam 12 in the z direction thus rotation of prism 16 can change the deviation angle a of laser beam 12 in the z direction compared to that of the optical axis 14. Rotation 20 of the second beam 18 about the optical axis 14 deviates the laser beam with respect to the x direction, i.e. rotation of this second prism 18 can deviate the laser beam 12 such that the angle b of deviation from the optical axis 14 is changed, thus by appropriate rotation of the first 16 and second 18 prisms, the deviation angles a and b are reduced to zero and the laser beam then lies on the optical axis 14.

The prisms may be rotated via manual or computer control.

Fig 2 shows schematically an alternate laser system according to the invention having a laser source 30 which provides a laser beam 32 which is initially oblique to a first optical axis 33 and orthogonal to a second optical axis 34.

In order to deviate the laser beam 32 orthogonally, a mirror 42 is provided as well as first 36 and second 38 prisms. The mirror 42 is angularly offset to the second optical axis 34 so that when a laser beam is reflected off the mirror, the laser beam is deviated in

two planes i.e. the mirror is tilted or non-perpendicular with respect to the x,y and z axes. The position of the mirror 42 is fixed with respect to the laser source 30 and the first optical axis 33 at approximately the right orientation to achieve orthogonal deflection of the laser beam. The two prisms 36,38 which are rotatable 40 to deviate the laser beam 32 in two planes are used to fine-tune the effect of the mirror 42.

In other words, as it is difficult to angularly align a mirror in order to achieve true orthogonal deflection of a laser beam which is incident thereon, this embodiment of the invention allows for small deviations from true alignment during assembly of a laser system to be accommodated. In a conventional laser system, the mirror is aligned using a micrometer, screw thread or differential screw. These adjusters remain in the laser system which increases the sensitivity of the system to temperature fluctuations as the adjusters are made from a material (steel) which has a different thermal expansion coefficient to the mirror material. Due to the design of the adjusters, a linear expansion of the adjuster results in a rotational movement of the mirror, which, if large enough will result in misalignment. In addition, these adjusters are difficult to use to realign the mirror. The prisms of the present invention may be mounted within an aluminium ring which locates the prisms and enables adjustment thereof. Although temperature fluctuations will still cause expansion of the rings, as the prism is within the ring, such expansion will stretch the prism linearly not rotationally. Thus a laser system according to the invention is less sensitive to changes

in temperature.

A further advantage is that if it is required to move the beam by an angle θ, the mirror must be moved by $\theta/2$. If θ is small then this may be time consuming and difficult to achieve whereas deviation by a manual or motor-driven rotatable prism is easier (this can be done using an actuator which has one end remote from the prism) and although there is a relationship between prism rotation and beam deviation the prism can be selected such that a larger scale rotation of the prism results in a beam deviation of θ.

In an alternative arrangement, the first and second beam steering prisms can be located after the mirror so the laser beam path is fine-tuned after reflection..

Although in this example, the laser beam, is orthogonal to the optical axis of the laser system, the person skilled in the art will appreciate that any angular deviation is possible with this embodiment of the invention by appropriate orientation of the respective parts of the laser system or the addition of more mirrors, for example.

Fig 3 shows an interferometer system 50 having a combined laser source and detector 51 which produces a laser beam 52. A beam splitter 53 splits the laser beam into two sub-beams 52a and 52b which are subsequently directed to individual mirrors 55a,55b respectively which are secured to relatively movable objects (not shown). In the example shown, the mirrors are approximately parallel to each other and lie on optical axis 60 of the interferometer. This optical

axis lies orthogonally to the laser source 51. The mirrors 55a,55b reflect the laser sub-beams 52a,52b which are subsequently recombined at the beam splitter 53 producing an interference beam which is detected by the combined laser source and detector 51. This interference beam gives information about the relative positions of the two objects (not shown).

In order to produce the two spaced apart sub-beams characteristic of an interferometer one of the sub-beams 52b is directed to a retroreflector 54 located adjacent the beam splitter whereas the other sub-beam 52a is directed to a mirror 56 placed away from the beam splitter 53 at 45° to the laser sub-beam path, the mirror 56 and retroreflector 54 each direct a respective sub-beam towards the individual mirrors 55a and 55b. In the path of each sub-beam, between mirror 56 or retroreflector 54 and individual mirrors 55a,55b are two sets of two rotatable prisms 57a,58a and 57b,58b one set of prisms lying in the path of each sub-beam 52a,52b respectively. These prisms are rotatable about the axis of the sub-beams and can be disposed such that rotation of one prism 57a,57b causes deviation of the respective sub-beam 52a,52b out of the plane of the paper whereas rotation of the other prism 58a,58b causes deviation of the sub-beam in the plane of the paper. It is preferred that the pairs of prisms 57,58 are arranged so that the beam deviations resulting from rotation of each prism are substantially orthogonal over a small angular range (between 70 and 110°, or about 90°). This allows control of the direction of each sub-beam 52a,52b in two-dimensions (which are not necessarily orthogonal), independently of the other sub-beam.

This increases the tolerance of the system to misalignments of optical components within the system, in particular to the relatively movable individual mirrors 55a,55b, which may introduce misalignments during their relative movements.

The interferometer system shown in Fig 3 could be adapted for use with the embodiment of the invention which uses an angularly offset mirror in addition to the two rotatable prisms in order to achieve larger laser beam deviations for one or both of the sub-beams. Depending on the requirements, the angular alignment of the sub-beams could comprise completely separate systems (as shown in Fig 3) or one or more parts could be shared by the sub-beams.

The two prisms described herein could be replaced by known configurations of one or more prisms depending on requirements as to number of dimensions or deviation required and the important of limiting chromatic aberrations.

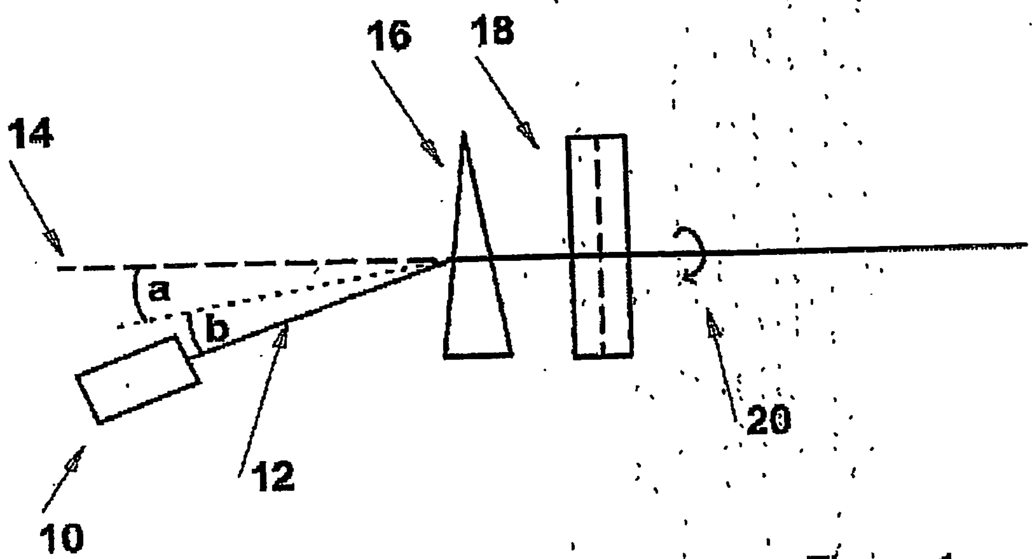

Figure 1

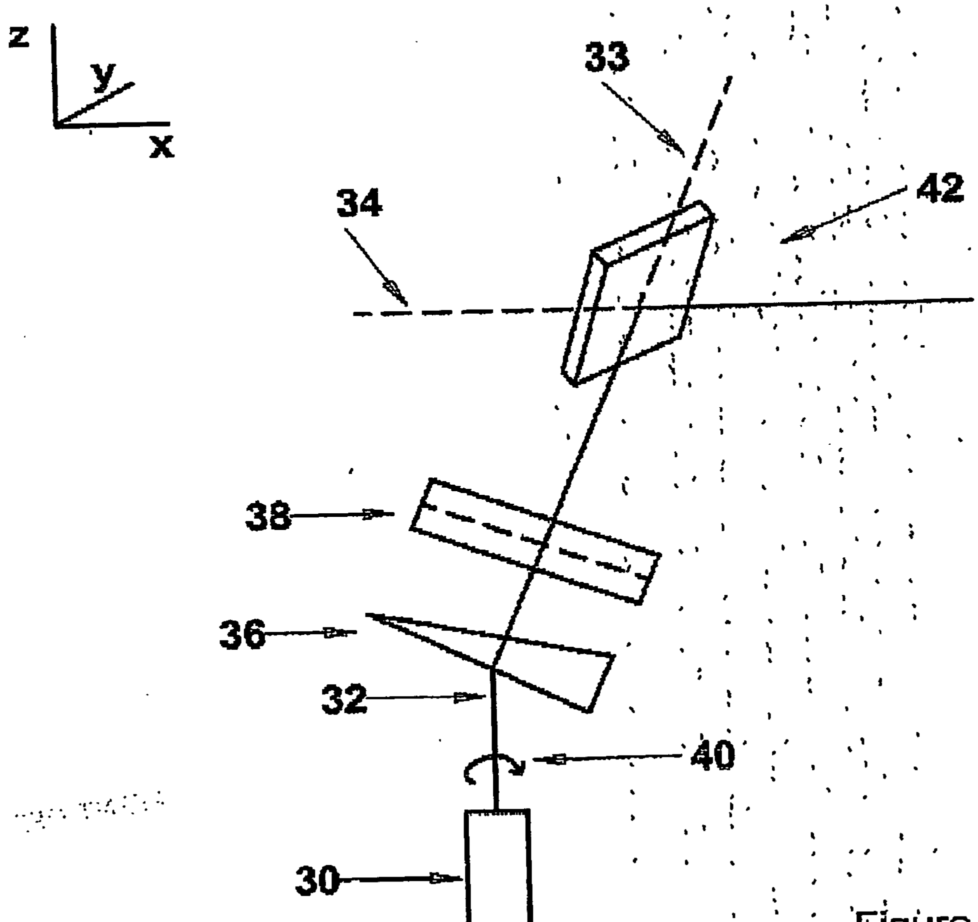

Figure 2

2/2

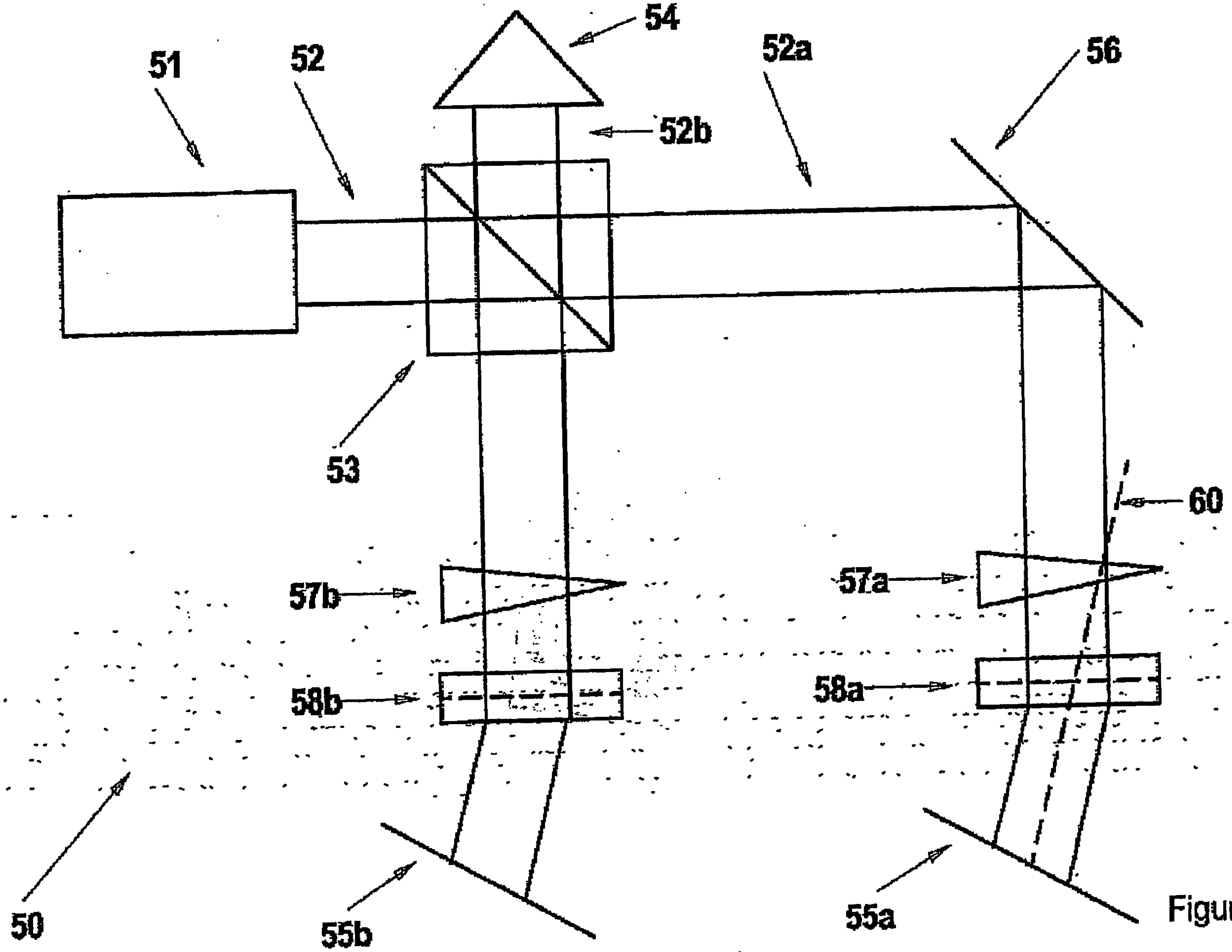

Figure 3